"The Spectra of Metallic Arcs in an Exhausted Globe." By A. FOWLER, A.R.C.Sc., F.R.A.S., and HOWARD PAYN, F.R.A.S. Communicated by Sir NORMAN LOCKYER, K.C.B., LL.D., F.R.S. Received June 10,—Read June 18, 1903.

[PLATE 14.]

Working on the supposition that the bands which occur in the arc spectrum of magnesium are due to possible combinations of the metal with gases in the outer part of the arc, we have recently attempted to obtain the line spectrum free from bands by photographing the spectrum when the arc is passed in an exhausted globe. It is found, however, that while the band beginning at λ 5007·5 is sometimes greatly reduced in intensity under these conditions, the bands attributed to "magnesium hydride" by Messrs. Liveing and Dewar* are very strongly developed.

Besides this, the characteristic spark, or "enhanced" line at λ 4481·3, which is almost invisible in the ordinary arc in air, is one of the strongest lines in the spectrum. Special interest attaches to this line on account of its application to the determination of relative stellar temperatures, based on the variations in the spectrum of magnesium under different conditions, which were first systematically investigated in relation to temperature by Sir Norman Lockyer in 1879.†

The occurrence of the line 4481 in the arc spectrum under special conditions was first recorded by Liveing and Dewar in 1888‡, and has since been investigated by other observers. Crew§ found that the line appeared in the spectrum of magnesium when the arc was surrounded by an atmosphere of hydrogen, and a little later Porter‖ found among other results, that a similar effect was produced by oxygen. Experiments by Sir Norman Lockyer and the writers have confirmed these observations.

More recently, Hartmann and Eberhard¶ have observed that enhanced lines appear in the arc spectra of magnesium, zinc, and cadmium when the arc is made to pass in water. The spectra obtained in this manner are stated to be almost identical with those obtained when the arc is passed in a current of hydrogren, and the opinion is expressed that the change is produced by hydrogen released by electrolysis around the electrodes in water. Hartmann has since found

* 'Roy. Soc. Proc.,' vol. 32, p. 196.

† 'Roy. Soc. Proc.,' vol. 30, p. 29; also 'Chemistry of the Sun,' p. 242; and 'Inorganic Evolution,' p. 75.

‡ 'Roy. Soc. Proc.,' vol. 44, p. 241.

§ 'Astrophys. Journ.,' vol. 12, p. 167, 1900.

‖ 'Astrophys. Journ.,' vol. 15, p. 281, 1902.

¶ 'Sitz. der Preuss. Akad. der Wiss.,' 1903, IV, p. 40; 'Astrophys. Journ.,' vol. 17, p. 229.

that the magnesium line 4481 becomes stronger in the spectrum of the metallic arc in air as the current strength is lessened.*

The occurrence of enhanced lines in the spectrum of the arc at reduced pressure, however, does not appear to have been previously recorded, and it may, therefore, be useful to state briefly the results which have been obtained.

Method of Experiment.

The experiments were conveniently made by enclosing the arc in a glass globe of about a litre capacity having two necks and an outlet by which connection was made with a Töppler pump. Short rods of the metal to be experimented upon were attached to brass rods passed through the two necks and made air-tight with a packing of rubber tube and Chatterton's compound.

The pole pieces were put nearly in contact, so that a slight pressure on one of them sufficed to strike the arc. With this arrangement the arc can only be observed for a comparatively short time owing to the burning away of the poles, and the experiment is also interrupted by the formation of a deposit on the interior of the globe. Still it is usually possible to take two or three photographs in each setting up of the apparatus. Ordinary commercial metals cast into rods a quarter of an inch in diameter were used.

[*Note added July* 16.—In each case the exhaustion was carried as far as the nature of the apparatus would permit. The pressure on starting the arc was from 1 to 2 mm.

The current was obtained from a 100-volt circuit, and in a repetition of the experiment with magnesium poles, measurements have shown that the current strength usually employed was 7 ampères for the arc in air and 8 for the arc under reduced pressure.]

Magnesium.

The well-known triplets beginning at 5183·84 (b_1) and 3838·44 are apparently little affected when the globe is exhausted, but the lines 5528·75, 4703·33, 4352·18, 4167·81, 4058·45, and 3987·08, which form a regular series,† are usually sharper than in the ordinary arc, and in some photographs four additional members of the series are seen (approximate wave-lengths 3938, 3904, 3879, 3860).

The band 5007·5, as already remarked, is generally reduced in intensity, while the "hydride" bands, beginning at 5618, 5210, 4849,

* 'Sitz. der Preuss. Akad. der Wiss.,' 1903, XII, p. 234; 'Astrophysical Journ.,' vol. 17, p. 270.

† Rydberg, 'Öfversigt af Kongl. Vet. Akad. Forhandl.,' 1893, Stockholm.

appear with great intensity. Flutings of nitrogen also appear in some of the photographs.

The enhanced line 4481·3 is of about the same intensity as b_1, and stronger than the lines 4703 and 4352. It is also notably sharp as compared with its usually hazy appearance in the spark spectrum of the metal.

Two conspicuous pairs of sharply defined lines which appear at approximate wave-lengths 4385, 4391 and 4428, 4434 cannot be traced to any known impurities, and a comparison with the spark spectrum leaves no doubt that they are true enhanced lines of magnesium. They are very ill-defined in the ordinary spark, but are distinctly visible as double lines in a photograph of the spark spectrum when a small amount of self-induction is introduced into the secondary circuit, though disappearing when the self-induction is increased. The line at 4391 is apparently identical with the enhanced line recorded by Sir Norman Lockyer* at 4395. Porter† has observed lines at approximate wave-lengths 4390, 4430 and 4434 in the spectrum of the magnesium arc in an atmosphere of ammonia or oxygen which probably correspond with three of the above four lines, but states that he has not succeeded in identifying them.

Another spark line of small intensity recorded by Thalèn and others at λ 4587 does not appear in the photographs of the spectrum of the arc in the exhausted globe, but Porter finds it among the lines of the magnesium arc in ammonia.

It is important to note also that in some of the photographs there is a distinct line coincident with the F (H_β) line of hydrogen.

[*Note added July* 16.—The identification of this line has been confirmed by visual observations showing the presence of both H_β and H_α.]

Another point of importance, in considerations as to temperature conditions, is that the flutings and enhanced lines appear to originate in different parts of the arc.

Zinc.

The strong triplet of lines at $\lambda\lambda$ 4810·71, 4722·26, 4680·38, and the adjacent line 4630·06, appear as strong lines, but are generally sharper than the corresponding lines in the spectrum of the arc in air at atmospheric pressure. Most of the other lines in the region D to K disappear altogether or are greatly reduced in intensity.

The well-known spark lines 4912·2, 4924·8 (Thalèn's wave-lengths corrected to Rowland's scale) make their appearance with considerable

* 'Roy. Soc. Proc.,' vol. 61, p. 163.

† 'Astrophys. Journ.,' vol. 15, p. 277.

intensity, though they are less striking than the principal enhanced lines which appear in the case of magnesium (Plate 14).

Strong flutings also appear, the principal one commencing with a sharp head near λ 4300 and grading off towards the violet. These are identical with flutings which appear in the spectrum of the arc when zinc poles are surrounded by an atmosphere of hydrogen, and may therefore be provisionally attributed to "zinc hydride." These flutings have also been observed in the zinc arc in hydrogen by Basquin,* who also "in lieu of a better hypothesis" attributes them to a compound of hydrogen with the metal.

In one experiment the stronger flutings of nitrogen appeared in the spectrum, but they were apparently restricted to the region surrounding one of the poles. The F line of hydrogen also appears in some of the photographs.

As in the case of magnesium, there is evidence that the flutings and enhanced lines do not originate in the same part of the arc.

Cadmium.

The phenomena are generally similar to those observed in the case of zinc, but some of the features are less marked. The strong triplet λλ 5086·06, 4800·09, 4678·37 and the adjacent line 4662·69 are of reduced intensity, but more sharply defined than in the ordinary arc, while most of the other arc lines in the region D to K disappear. The spark lines 5379·3, 5338·6 are certainly present but not conspicuous.

Strong flutings, fading towards the violet, are seen, the principal heads having approximate wave-lengths, 4491 and 4298. Here, again, the flutings are identical with those which appear when the cadmium arc is surrounded by hydrogen, and may therefore be provisionally regarded as originating in "cadmium hydride."

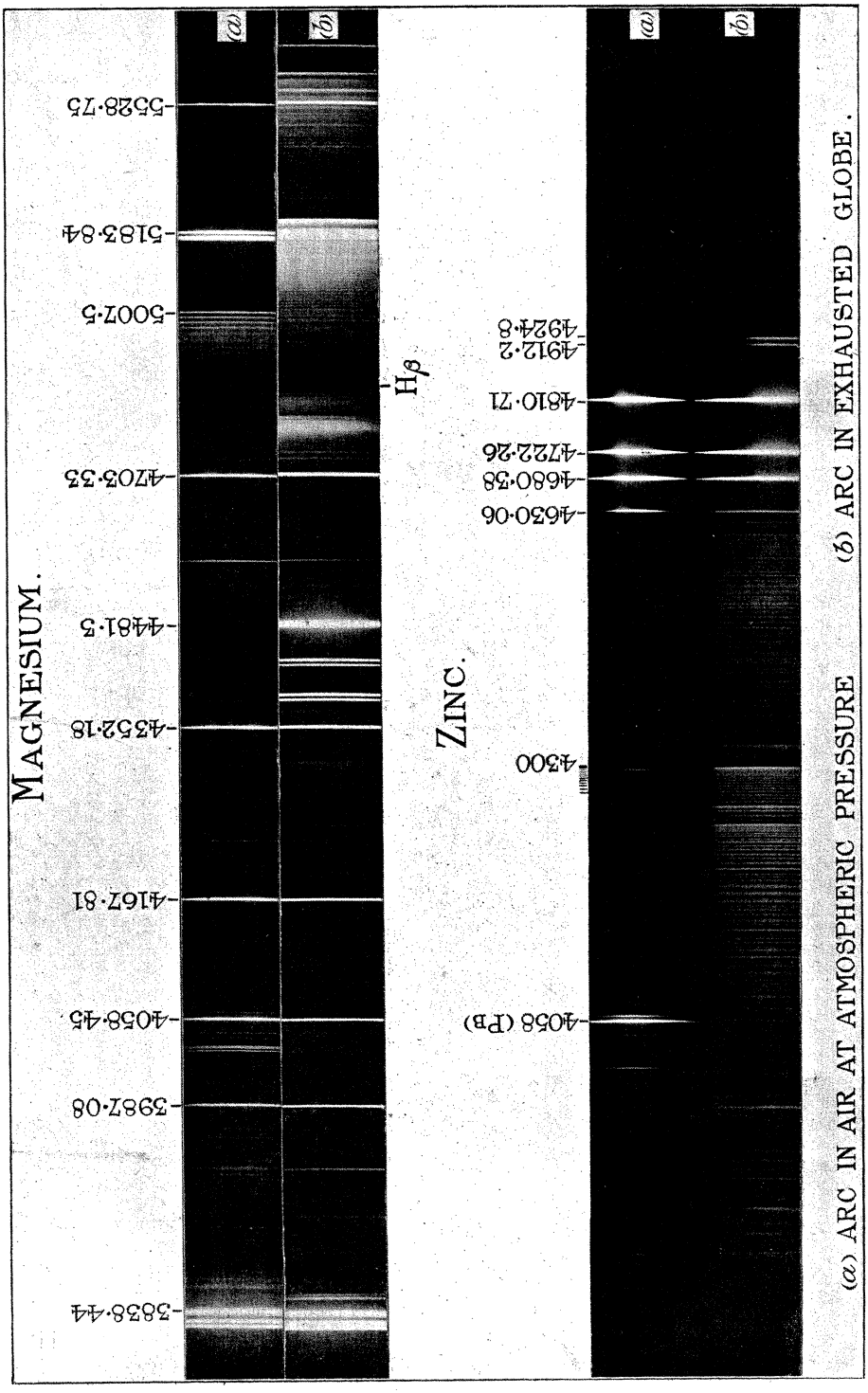
The F line of hydrogen, if present, is too feeble to be shown in the photographs.

Iron.

It is only after careful examination that the spectrum of an iron arc in an exhausted globe is seen to be materially different from that of the arc in air at atmospheric pressure. Nevertheless, there is no doubt as to the appearance of the principal enhanced lines, among them being 5018·13 and 4584·02.

The F line of hydrogen is not certainly present, but it could not be distinguished from the neighbouring iron line with the dispersion employed unless comparatively strong.

* 'Astrophys. Journ.,' vol. 14, p. 10, 1901.


MAGNESIUM.
(a)
(b)
5528·75
5183·84
5007·5
4703·75
4481·5
4352·18
4167·81
4058·45
3987·08
3838·44
H_β
ZINC.
(a)
(b)
4912·2
4924·8
4810·71
4722·26
4680·58
4630·06
4300
4058 (PB)
(a) ARC IN AIR AT ATMOSPHERIC PRESSURE
(b) ARC IN EXHAUSTED GLOBE.

General Conclusion.

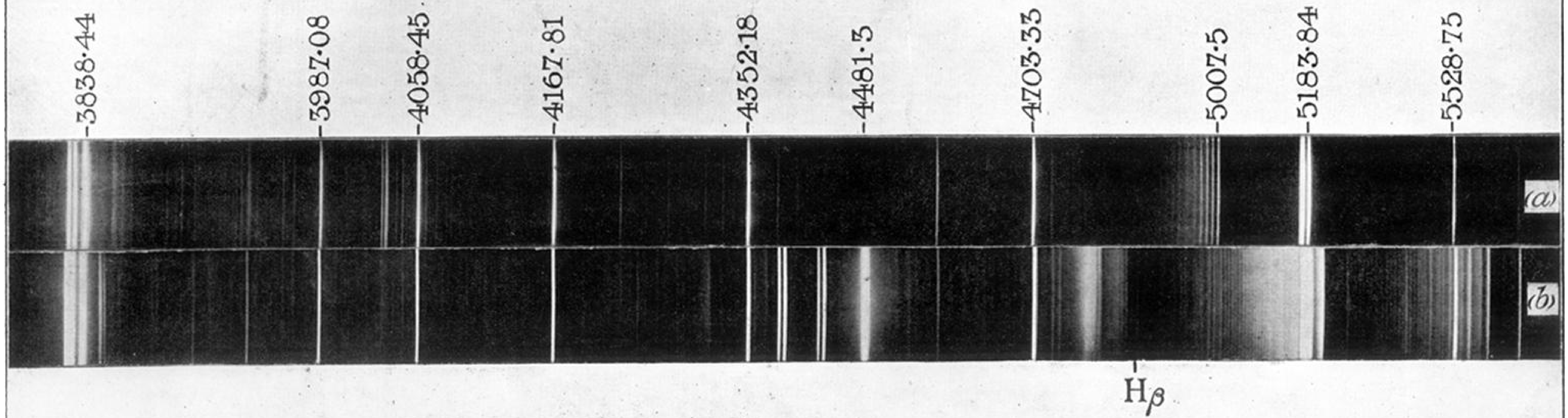
So far as they go, the experiments seem to suggest that the modifications of the arc spectra in an exhausted globe may be due to the presence of hydrogen liberated from the heated poles. It has already been pointed out that one of the effects of a hydrogen atmosphere on a metallic arc is to introduce enhanced lines into the spectrum, and the presence of hydrogen under the new conditions of experiment is indicated in the case of magnesium and zinc by the appearance of the H_β line, and in magnesium, zinc, and cadmium by flutings which are known to appear in the presence of hydrogen.

It is well known that hydrogen is occluded by many metals, and experiments made to determine the relative amounts of the gas given off on heating *in vacuo* show that the amounts are roughly proportional to the relative strengths of the enhanced lines appearing when the arc passes in the exhausted globe; that is, magnesium and zinc gave off the greatest quantities of the gas, cadmium the least, and iron an intermediate amount. The apparent absence of the F line in the spectra of cadmium and iron in the exhausted globe may, therefore, be due to its feeble intensity on account of the smaller quantity of gas driven out, while the absence of "hydride" bands in the case of iron may perhaps be explained by supposing that combination of hydrogen with iron does not readily take place.

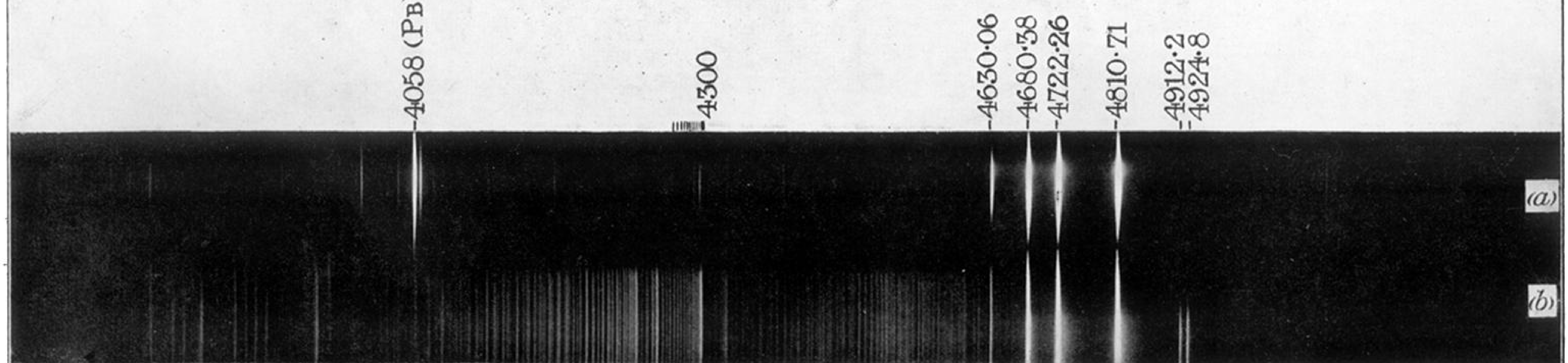
The exact nature of the action of hydrogen on the arc requires further investigation.

The experiments described in the foregoing paper have been made in Sir Norman Lockyer's laboratory, to whom we desire to express our thanks for the privileges afforded. We also wish to express our thanks to Mr. F. W. Jordan for assistance in carrying out the experiments.

MAGNESIUM.



ZINC.



(a) ARC IN AIR AT ATMOSPHERIC PRESSURE (b) ARC IN EXHAUSTED GLOBE.